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AIR COMMAND AND STAFF COLLEGE

STUDENT REPORT

ANALYSIS OF BASE CIVIL ENGINEERING GENERAL PURPOSE VEHICLE TABLE OF ALLOWANCES

MAJOR JOBE CARLTON TICKEL 84-2575

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Submitted to the faculty in partial fulfillment of requirements for graduation.

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Presents an improved Basis of Issue (BOI) for determining the Base Civil Engineering General Purpose Vehicle Allowances based upon analysis of workload, production output, and manpower strength of 25 AF BCE units, utilizing coefficient of correlation and linear regression. The vehicle fleet sizes of 20 civilian businesses were compared. The recommended BOI, represented by the newly developed equation, Y=.4+.5X better reflects BCE vehicle needs, (X=shop manpower, Y=shop's vehicle allowance) than the present BOI.

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PREFACE

1. The Air Force Engineering and Services (E&S) community, spearheaded by Headquarters, United States Air Force, Directorate of Engineering and Services (HQ USAF/LEE), has developed a strategic plan. The plan outlines the objectives, specific projects, and needs of E&S. The purpose of the plan is to ensure that E&S prepares properly for operation in the year 2000.

2. One objective of the plan is to review, modernize, and expand Table of Allowances for the purpose of improving the productivity and efficiency of Engineering and Services operations. One specific review involves civil engineering vehicles.

3. This project was undertaken to assist E&S efforts in the review of civil engineering general purpose vehicle needs. The study will be provided to the Air Force Engineering and Services Center (AFESC) for use in substantiating increased BCE vehicle needs air force wide as AFESC is responsible for this activity.

4. Acknowledgement is given to the following organizations, most helpful in providing information, assistance, and guidance: Headquarters Air Force Engineering and Services Center, Product Management and Maintenance Management Divisions (AFESC/PQP and AFESC/DEMG), and Headquarters, Military Airlift Command, Maintenance Management and Vehicle Authorization and Allowance Divisions (HQ MAC/DEMG and HQ MAC/LGSE).

ABOUT THE AUTHOR

Major J. Carlton Tickel is a Base Civil Engineering Officer with 11 years experience. He received a Bachelor of Science degree in Industrial Engineering and Operations Research from Virginia Polytechnic Institute and State University in 1972. He entered the Air Force at Craig AFB, Alabama in 1973. Major Tickel earned a Master of Business Administration degree from Troy State University in 1976. He has held numerous positions both in Base Civil Engineering organizations and at Major Command Headquarters. His positions have included: Base Industrial Engineer, Chief of Operations and Maintenance, Chief of Housing, MAJCOM Industrial Engineer, MAJCOM Chief, Maintenance Management Division, and Executive Officer to the DCS/Engineering and Services, Headquarters, Military Airlift Command. Major Tickel attended Squadron Officer School in residence; and, is currently attending the Air Command and Staff College in residence.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

TABLES

FIGURES

EXECUTIVE SUMMARY

REPORT NUMBER 84-2575

AUTHOR(S) Major Jobe Carlton Tickel, USAF

TITLE ANALYSIS OF BASE CIVIL ENGINEERING GENERAL PURPOSE VEHICLE TABLE OF ALLOWANCES

I. Problem: Many Base Civil Engineering organizations have argued that they do not have a sufficient number of general purpose vehicles to transport their people to the base work-sites.

II. Purpose: To prove the statement "the current Table of Allowances (TA) for general purpose vehicles allows the Base Civil Engineer too few vehicles to productively employ the unit's workforce;" and, if found true, to recommend a revised allowance that does provide an adequate number of vehicles.

III. Objectives:

A. To investigate the relationship between Air Force BCE vehicle fleet sizes and the fleet sizes of similar civilian businesses.

B. To investigate the degree of correlation between shop vehicle allowance, manpower, workload, and production output. To determine which of these factors should be used to develop a linear equation that better represents BCE vehicle needs; and, to derive that equation.

C. To compare the results of "B" with the present TA Basis of Issue (BOI). To recommend the Air Force utilize whichever BOI allows the most productive use of BCE resources.

IV. Discussion of Analysis:

A. Twenty companies were surveyed concerning their vehicle requirements. In general, civilian firms maximize personnel productivity by assigning a vehicle to every 1.1 person. Two and three man crews were not found to be cost effective with the exception of use on the largest maintenance jobs.

B. Data from 25 AF bases were collected to compare each of thirteen workload/production output factors to the manpower strengths of five work centers. A coefficient of correlation analysis was conducted to find the most significantly related data.

V. Findings:

A. There is a significant difference, over 300%, between industry and Air Force vehicle allowance policies.

B. The correlation analyses suggest a significant relationship between shop manpower and three workload factors: total base building floor space, total cost of facilities, and base population. In addition, a high degree of correlation was found to exist between manpower and the production output factors of number of vehicles required to accomplish 100 jobs (based upon crew size) and work orders completed per month.

VI. Conclusions:

A. The 300% difference between the AF and industry vehicle allowance policies is too great to ignore. Industry must be utilizing manpower at a highly productive rate or be experiencing losses that would warrant a change. Since BCE vehicle allowances are considerably lower, perhaps, the BCE is not maximizing manpower productivity.

CONTINUED

B. The linear equation resulting from statistically regressing the significant relationships in Finding B is: Y=.4+.5X, that is, one vehicle for every two workers (X=manpower, Y=vehicle requirements).

C. It was determined that the above relationship better represents BCE vehicle needs that the p sent BOI. The new equation produces a higher degree of rrelation between manpower and vehicles required.

VII. Recommendation: Air Force Civil Engine ing should adopt the general purpose vehicle BOI, Y+.4+.5X (1 e cle/2 workers), when determining the vehicle requirements of t e five shops represented in this study (Carpentry, Plumbing, Heating, Refrigeration and Air Conditioning, and Interior Electric).

Chapter One

INTRODUCTION

Today, we live in a highly mobile world that relies on a variety of travel modes which vary from walking to sophisticated air travel arrangements. People generally select the travel mode that best suits their particular needs; and, they base their selection on a number of factors. A list of factors might include: the distance to be travelled, the capacity required, allowable travel time, and an economical use of available resources, i.e., people and dollars (22:6).

The most popular mode of transportation is the four wheeled vehicle because of its convenience, relatively cheap cost, and accessibility. Needless to say, there are a wide variety of four-wheeled vehicles on the market to choose from. For example, one could choose pick-up trucks, vans, station wagons, imported cars, or standard size automobiles. People buy vehicles for work, family use, and pleasure. Businesses procure vehicles to accomplish a variety of jobs. The decisions of what to buy and how many to buy are important because they directly impact the buyer's ability to effectively and efficiently use resources. Determining what to buy in relation to business requirements constitutes the businesses' mix of resources (21:11). Businesses that develop a " proper resource mix" are generally successful; those who do not, usually have troubles (20:5).

The Air Force Base Civil Engineering unit is a business, so to speak, that provides a service to air force bases. The Base Civil Engineer (BCE) constantly seeks ways to improve his/her resource mix, i.e.,to achieve the "proper mix" that will allow the organization to successfully accomplish its job of maintaining the base (23:6).

The BCE's goal, as listed in Air Force Regulation 85-1, "Resources and Work Force Management," is:

> . . . to provide an operational installation capable of supporting the mission, including the development and implementation of programs designed to improve the livability of the base community. Maintenance management procedures are important, because they provide a framework for an orderly process that matches available resources with requirements (12:9).

It is important for a base and the BCE to match available resources with mission requirements because the BCE budget accounts for 40 to 60 percent of each bases' Operations and Maintenance budget. Even small changes in resource allocation could potentially affect a significant number of dollars (15:3). Consequently, this large proportion of the budget must be effectively and efficiently allocated to prevent wasting government funds.

The BCE is responsible for maintaining all base facilities. The responsibility encompasses just about every conceivable location from one end of a base to the other including runways, roads, and open fields. A considerable number of vehicles are needed to carry out this responsibility. The BCE relies on what are commonly called, in the Air Force, general purpose vehicles, to move people from the civil engineering compound to various job sites around a base.

The BCE must follow the Air Force Table of Allowances (TA) guidelines when requesting vehicles (19:5). TA 010 "Table of Allowance Document" is the specific document that lists vehicle allowances by vehicle type and organization.

There are four types of vehicles that fulfill civil engineering's general purpose vehicle needs. They are: 1) Multi-stop Truck (National Stock Number (NSN) 2320-00-72-5877), 2) Telephone Maintenance Truck (NSN 2320-00-801-9193), 3) Panel Truck, 1 ton (NSN 2320-01-013-2754), and 4) Compact Telephone Maintenance Truck (NSN 2320-01-093-9621) (14:C-5).

The TA Basis of Issue (BOI) provides, by shop, the shops total general purpose vehicle allowance. The BOI for BCE shops is determined by the number of people authorized in the shop. For example, if there are six people in a particular shop, the BOI allows two vehicles. Appendix A gives an example of TA 010 and typical BOI allowances. Any combination of the four vehicle types may be designated when developing a particular shop's vehicle authorization list.

For the purpose of this study, only the total allowances will be analyzed since it is usually left to the BCE to determine the vehicle combination. Having too many vehicles wastes vehicle resources. On the other hand, having too few vehicles wastes manpower. Manpower costs range from five to ten times the cost of transportation (i.e. cost of general purpose vehicles) (15:3). Thus, vehicle allowance studies could prove beneficial and helpful toward maximizing the BCE's ability to support the base mission.

There are normally 18 different BCE shops within a BCE organization. This study will review the general purpose vehicle requirements for five BCE work centers. The centers to be studied are: Carpenter, Plumbing, Heating, Refrigeration and Air Conditioning, and Interior Electric work centers (shops). A work center is defined as the smallest office within a BCE organization which is organized on the basis of one specific skill per shop (12:6). The work centers chosen for study represent small job intensive work centers usually requiring more crews and travel time. Consequently, these shops would be expected to have a higher need for TA adjustment, if any is needed, than the other BCE work centers.

Industry defines productivity as "a measure of the relationship of resources used and quantity of output" (2:2). The Air Force BCE definition of productivity, according to "The Productivity Management Guide for U.S. Air Force Base Civil Engineering," is:

> . . . the ability to do each task efficiently and to organize the entire work accomplishment process so that the results are effective in supporting the base mission (13:3).

Therefore, on the basis of the above definitions, the BCE's workforce equates to the "resources used" portion of the first definition, and the base mission reflects output. Productivity is directly related to how well the workforce accomplishes its mission.

Many factors affect BCE productivity. For example, labor is an important consideration because of high salaries and associated costs involved in maintaining a skilled workforce. Other factors that influence productivity include technological advances in equipment, job and material planning, the physical environment the organization works in, rules and regulations the unit must follow, and management's ability to maximize productivity (13:5).

Causes of lost BCE productivity are shown in the chart in Appendix B. Typical causes include: inadequate tools and equipment, inadequate training, excess transit time, and wasted time. Technology includes having state of the art equipment, adequate and sufficient materials, and not the least of importance, quality and sufficient numbers of vehicles. The workforce must have the best tools and equipment to maintain productivity in the face of rising manpower costs and manpower cuts. Thus, providing the right types and total number of transportation vehicles, i.e., the proper mix of vehicles, could assist in improving productivity (3:42).

PROBLEM

Many base civil engineering organizations have argued that they do not have a sufficient number of general purpose vehicles to properly transport their people to the various base worksites. A shortage of vehicles can reduce productivity by increasing worker transportation waiting time, and/or forcing management to send out larger crews than necessary. Both situations can result in lower job accomplishment rates. Therefore, if a BCE could develop and obtain a mix of vehicles which would provide better utilization of manpower than currently exists, an organization's productivity should improve.

PURPOSE

The purpose of this study is twofold: 1) to prove the statement "The current table of allowances for general purpose vehicles allows the Base Civil Engineer too few vehicles to productively employ the unit's workforce", and 2) if found true, to recommend an improved Air Force Table of Allowances that affords the BCE a greater number of vehicles. It is important that transport vehicles be available when needed, without delay, so valuable, i.e. costly, manpower resources are utilized to the best of the government's ability.

STUDY OBJECTIVES

First, investigate the relationship between AF BCE vehicle fleet size and the fleet size of selected industries. The selected businesses provide services to their respective customers similar to what the BCE unit provides the base mission. The industry information will be compared to the BCE data for any relationships that may exist between the respective crew sizes and the vehicle fleet sizes as a means of evaluating the productivity of the BCE workforce.

Second, investigate whether correlation exists between the size of a work center's vehicle fleet, its workload, and its productivity. These factors should provide insight regarding the number of vehicles required by a work center to do its job.

Third, the study will compare required vehicles based upon the second objective above, with the current Table of Allowances. If the investigation determines a Basis of Issue (BOI) that improves productivity, a new BOI will be recommended.

METHODOLOGY

The research methods involved in analyzing each of the three objectives were:

1) Contact 20 randomly selected companies by telephone survey to request information about each's vehicle fleet (refer to Appendix C for a list). The information was then compared with the size of selected AF BCE vehicle fleets for similarities and conclusions.

2) Workload data was collected for 25 randomly selected BCE units throughout CONUS (listed in Appendix D). Descriptive information, such as base size, population, etc., was obtained from the General Services Administration catalog of military bases (18:passim). Manpower strength and job sampling data were obtained from the

Air Force Engineering and Services Center (AFESC) and the Military Airlift Command (MAC).

All information was evaluated utilizing the statistical techniques of linear regression and coefficient of correlation. (4:230,246).

3) The results of step two above were analyzed. The strongest relationships between manpower and vehicle requirements were selected to determine whether they were significant. A linear equation was calculated for the most significantly related data. This equation, representing the relationship between the variables can be used to determine a shops' vehicle requirements.

FINDINGS

Industries' vehicle requirements are based upon manpower. They make every effort to maximize their manpower productivity by minimizing vehicle problems. Industry assigns a vehicle to every 1.1 person.

There is significant relationship between manpower and workload. There is a significant relationship between manpower strengths and the number of crews needed to accomplish a sample of 100 jobs. Based upon crews needed, the number of vehicles needed (to support the crews) were determined.

The relationship between manpower and vehicles (as determined above) was found to be significant, also. Therefore, on the basis of these findings, an equation representing the relationship between manpower and vehicles was determined to be Y=.4 + .5X. This equation better represents BCE vehicle needs than the present Basis of Issue.

A detailed discussion of these findings and their analysis is presented in the following chapters. Chapter Two will discuss the vehicle requirements of the BCE unit compared to industry. Chapter Three will discuss the relationship of vehicles to productivity. Lastly, Chapter Four will present conclusions and recommendations.

Chapter Two

BASE CIVIL ENGINEERING VERSUS INDUSTRY VEHICLE REQUIREMENTS

Many civilian companies provide the same types of services as the base civil engineering unit. Construction contractors perform carpentry work. The telephone, gas, and power companies service a communities' utilities much the same way the BCE unit services base utilities. Sears Corporation provides a myriad of services from installation of appliances, windows, electrical lines, etc., to servicing what they sell. Since these companies and the BCE unit provide similar types of services, it would seem logical that there would be similarities in vehicle requirements. Consequently, a list of factors used by industry to justify their vehicle requirements might provide useful insight when reviewed against the BCE's vehicle requirements.

A telephone survey was made of 20 companies to obtain information. The data collected was then used in the analyses that follow. The maintenance supervisor for each company was contacted. Each was asked the following five questions for the purpose of developing a baseline of information.

1) How many maintenance personnel do they have assigned to their day shift?

2) How many vehicles do they have available to transport the maintenance crews to their job sites?

3) Does the company have a policy for obtaining vehicles to transport their craftsmen? That is, do they base their decisions on a ratio of craftsmen to vehicles or by some other method or policy?

4) Does the company take into consideration travel time and distance when purchasing vehicles?

5) Do they have a method of evaluating their policies' effectiveness?

All the individuals spoken with were cordially responsive; and, it appeared that each attempted to provide accurate answers. All but two had more than five years experience in his/her respective position. On this basis, the information collected is considered to be valid and useful for the purposes of this study. Table 1 contains the data generated by the telephone survey while the following discussion summarizes the responses and general trends.

The first question concerned the size of their workforce during the dayshift. The question was restricted to the dayshift to eliminate the confusion of trying to separate any "after hours" workforce. The workforces varied from a low of five people to a high of 42. Universal agreement was found among the supervisors that manpower utilization was one of the most important aspects of their jobs.

Company	Number of Maintenance Personnel	Number of Vehicles	Pers./Vehicle
1	5	5	1.0
2	17	17	1.0
3	12	10	1.2
4	14	12	1.2
5	7	6	1.2
6	12	7	1.7
7	10	8	1.3
8	17	16	1.1
9	10	5	2.0
10	25	20	1.3
11	19	14	1.4
12	38	32	1.2
13	30	30	1.0
14	35	30	1.2
15	42	41	1.0
16	19	18	1.1
17	18	18	1.0
18	6	6	1.0
19	5	5	1.0
20	22	22	1.0
Total	363	322	1.1 Average

Table 1. Industry Vehicle Requirements

Each company determined a level of responsiveness acceptable to its customers, and sized its workforce accordingly. Generally, each company employed its workforce and located in an area that would allow them to maximize service response and capability. For example, Sears locates in areas that allow maximum coverage with minimal personnel.

The second question concerned the number of vehicles assigned to maintenance crews along with the policies involved in making vehicle assignments. The fleet sizes ranged from five to 41 vehicles. Seventeen out of 20 supervisors stated that their policy was to assign one person per vehicle, and on rare occasions, assigned two.

The supervisors responded to the third question by saying their policy was to accomplish as many jobs as possible per worker. They considered the procedure of assigning more than one person per vehicle unproductive and uneconomical because the high cost of manpower outweighed the comparatively low cost of vehicles.

The fourth question involved travel and distance considerations. Travel time was not considered an important factor. Seventy-five percent of the companies assigned their people to work in a specific city zone. This sometimes meant long beginning and end-of-day travel times. However, in general, the companies were not concerned about this. Eight out of 20 companies paid their employees only for one-way travel time anyway.

Fifth, how did they evaluate the effectiveness of their policies, and, were there any other applicable considerations? As common sense would indicate, they were interested in the "bottom line," i.e., profit. A craftsman and vehicle had to produce enough work to cover his/her wages, benefits, vehicle and associated maintenance costs. A per hour charge was calculated using these factors and customers were charged accordingly. When maintenance was completed in the estimated time, the charge covered expenses. Management, consequently, had to ensure that the workforce kept busy. Their management effectiveness was reflected or stated in the periodic profit and loss statements for the maintenance section.

The BCE does not have the profit motive requirement. However, a comparison can still be made. The BCE is required to "effectively and efficiently" utilize vehicles. According to Department of Defense, DOD 4500.36-R entitled "Management, Acquisition, and Use of Motor Vehicles," each user must "provide for the most economical use of manpower and equipment" (17:2-1). Industry attempts to maximize utilization of high cost manpower by ensuring enough vehicles are available. On the average, the companies contacted assigned 1.1 persons per vehicle or one person per vehicle 89% of the time. The remaining time, craftsmen doubled up, worked in the shop, or were on leave. The BCE attempts to achieve maximum utilization, too. While providing one vehicle for every person seems expensive, there should still be a method of determining the bottom-line requirement. The BCE unit receives no reimbursement for its work. Consequently, there is no direct way to equate revenues and expenses in order to evaluate effectiveness. But, we can conclude that industry realizes wasted manpower is more expensive than wasted transportation costs, and maintains a vehicle fleet considerably larger than the BCE's.

The BCE work centers evaluated ranged in size from seven to 50 people. The ratio of people per vehicle ranged from 3.5 to 4.5 people which exceeds 300 percent more people/vehicle than the observed industry average. This large variance indicates that there is a significant difference between the AF and industry vehicle allowance policies. Industry tries to maximize manpower's productivity; vehicle requirements are secondary.

In conclusion, the AF may not be maximizing productivity based upon such a significant difference between the respective ratios of vehicles to people. It is obvious though, that in both cases, manpower and workload determine vehicle requirements. The next chapter will look at factors that quantify the BCE's manpower and production output relative to vehicle requirements. While the industry review was informative the results discussed in the next chapter will provide the basis for recommending a change to the TA or not.

Chapter Three

CORRELATION OF VEHICLES TO PRODUCTIVITY

This chapter discusses the relationship between the size of a work center's vehicle fleet and various workload/productivity factors. The relationship between any two data variables can be determined by calculating their coefficient of correlation. The data utilized in these calculations, collected for the 25 CONUS bases, is presented in Appendix E. The data is being handled in this manner due to the scope of the study and quantity of data involved.

A sample size of 25 is considered representative of all Air Force bases based upon statistical evidence. There is 95 percent confidence that the means are representative of overall Air Force workload means (1:76). Since this sample is statistically meaningful, it can be used to derive conclusions for civil engineering units for the entire Air Force.

The data used for the study, as tabularized in the previously referenced appendix, were obtained from the following sources: Tables 3-8 were taken from the 1982 General Services Administration Listing of Government Property (18:passim). Tables 9-11, 13, 15, 17, 19, and 21-25 were obtained from the Air Force Engineering and Services Center at Tyndall AFB, Florida and the Military Airlift

Command at Scott AFB, Illinois. Tables 12, 14, 16, 18, and 20 were obtained by applying the general purpose vehicle Table of Allowances to each of the five work centers. The data was then analyzed for significance.

A total of 272 linear regression analyses were completed to determine the coefficient of correlation between various pairings of data. The following summarizes both the method and significant correlations found relative to each of the five work centers under scrutiny.

The first step in the analysis was to compare the relationships between the authorized manpower of the five work centers and basic workload factors. A basic workload factor is defined as a numerical representation of base size. The six factors chosen for comparison in relation to manpower were:

1) Base acreage (the size of the base).

2) The base military and civilian population (the number of people employed by the base).

3) Square feet of floor space (total amount of building floor space on a base, in millions of square feet, MSF).

4) Value of base facilities (the original cost of all base facilities, in millions of dollars, $M).

5) The total number of military family housing units on a base (MFH).

6) The total number of buildings located on the base.

Each summary explains the range and degree of correlation (significance) for the data analyzed. The manpower strength data does not change in each analysis. The range provides insight concerning the lowest and highest numbers in the data group. Each application of the coefficient of correlation equation compares a particular shop's manpower to a workload factor for each of the 25 sampled bases. The degree of correlation can vary from a low of -1.0 to a high of 1.0. The strongest or best correlation is 1.0 and represents a perfect relationship between the data compared. 1.0 means that as the independent variable (manpower) in the equation changes, the dependent variable (workload) varies in exactly the same way. That is, as one goes up the other goes up in exactly the same manner (4:248). For purposes of the study a correlation greater than or equal to .5 is considered significant. The data pairs showing the very highest degree's of correlation will be important because they provide the basis for retaining or improving the present BOI.

WORKLOAD ANALYSES

Each workload factor was compared to the manpower for each of the five shops which required six coefficient of correlation calculations. For example, the carpentry shop's manpower was compared to each of the six workload factors outlined above, and so on for each of the five work centers. The summaries below, grouped by workload factor, discuss the results.

The first analysis compared the base acreage to the authorized manpower strengths of the five work centers. The base's acreages ranged from a low of 604 acres to a high of 464,980 (424,000 range acres were dropped out of the calculations). The manpower strengths ranged from a low of seven to a high of 50. Applying the coefficient of correlation technique, it was found that the highest degree of correlation between these two sets of data was .43, for the plumbing shop, and, the lowest .23, for the interior electric shop. Thus, there is a small degree of correlation between acreage and manpower, but it is not significant.

The second analysis compared the base military and civilian population to the authorized manpower of the five work centers. The populations ranged from 2719 persons to 16,966. The same manpower data as above was employed. The correlation varied from a high of .75, for the relationship between population and the plumbing shop, to a low of .50, for the interior electric shop. This indicates that there is a significant degree of correlation between base populations and shop manpower.

The third analysis compared square feet of floor space to the manpower strengths. The floor space ranged from a low of 2.013 million square feet (MSF) to a high of 8.871 MSF. The manpower data remained constant. The correlations showed a high relationship of .86 for the carpentry shop to a low of .63 for the refrigeration shop.

This indicates that a very high correlation exists between manpower and building floor space. This is a significant relationship.

The fourth analysis compared the value of facilities ($million) to shop manpower. The facilities costs ranged from a low of $48.1 million to a high of $235.2 million. The highest degree of correlation was found to be .82, for the carpentry shop, to a low of .63, for the heating shop. Therefore, this data also exhibits a high degree of correlation.

The fifth analysis reflected the relationship between the number of base military family housing units and shop manpower. The lowest number of housing units was 264, the highest was 2470. It was determined that the highest degree of correlation was .69, for the interior electric shop versus a low of .37, for the refrigeration shop. This is considered a high correlation between the number of housing units and manpower.

The sixth analysis, and the last of the workload factor comparisons, correlated the number of buildings on each base to shop manpower. The number of buildings ranged from a low of 417 to a high of 2506. The results indicate a high correlation of .69, for the carpentry shop, to a low of .39, for the heating shop which means a fairly good degree of correlation exists between buildings and manpower.

PRODUCTION OUTPUT ANALYSES

The second set of correlation analyses compares production output factors and the manpower strengths of the five work centers. An output factor is a numerical count of work produced by the BCE workforce. The six factors selected for analysis are:

1) The average number of work orders accomplished by the BCE unit each month. Work orders are the large jobs that require the services of two or more shops.

2) The average number of job orders completed by the five shops each month. Job orders are the smaller jobs requiring work by only one shop.

3) Number of crews (actual). Calculated by randomly selecting a sample of 100 completed jobs and tabulating the crew sizes used to actually accomplish them.

4) Number of crews (standards). Calculated in the same manner as 3 except each job was evaluated against "Engineered Performance Standards" (EPS) to determine what the crew size should have been. EPS's are the accepted standard hours and crew sizes required to complete a job. The Department of Defense advocates the use of EPS because they can improve productivity (12:7).

5) Required number of vehicles (actual). The information in 3 was applied to the following equation to determine vehicle requirements. Y (vehicles required) = X (shop manpower) times percent of jobs using one man crews, + X/2 times percent of two man crews, + X/3 times the percent

of three man (or greater) crews. The result is Y; the required number of vehicles (actual), and is based upon the crew size actually used to accomplish the job.

6) Required number of vehicles (standards). The information in 4 above was applied to the equation in 5. The result is the number of vehicles (standards), and is a result of determining the crew size by applying EPS.

The same type of correlation analysis was performed as previously utilized in the workload analysis section of this chapter. The manpower strength data (which ranged from 7 to 50), again remains the same in each analysis. The relationships are summarized below.

The first analysis determined whether correlation exists between the average number of work orders (large jobs) accomplished per month and the work centers authorized manpower. The number of work orders ranged from a low of 11 to a high of 54. The data suggests a high correlation of .74 for the refrigeration shop, to a low of .61 for the plumbing shop. This means that a very strong relationship exists between manpower and work orders accomplished.

The second analysis compared the average number of job orders (small jobs) accomplished by these shops, per month, to their authorized manpower strengths. Job orders ranged from 102 to 760. The results showed the highest degree of correlation to be .78 for the refrigeration shop. The lowest correlation was .60 for the interior electric shop. Again, a very strong relationship between job orders accomplished and manpower was indicated.

The third set of analyses compared the number of crews (actual) to each shop's manpower. The number of crews ranged from 20 to 47. The correlation of crews with manpower ranged from a high of .46 for the plumbing shop, to a low of .29 for the interior electric shop. A low degree of correlation between these two factors was found to occur.

The fourth analysis compared the number of crews (standards) to manpower. The number of crews ranged from 41 to 57. The highest correlation was .49 for the heat shop; the lowest was .41 for the plumbing shop. This represents a better degree of correlation than that found for crews (actual), but the correlation remains low.

The fifth analysis compared the required number of vehicles based upon actual crew sizes and the manpower of each shop. The number of vehicles ranged from a low of 3 to a high of 12. Findings showed the high correlation to be .94 for the plumbing shop; the low was .62 for the interior electric shop. An excellent degree of correlation exists between these two factors.

The last analysis compared manpower to vehicles required (standards) for the same 100 jobs, taking into account that crew sizes were determined by those given in the Engineered Performance Standards. The "enhanced" number of vehicles ranged from 3 to 15. The correlations show a high of .96 for the Plumbing shop to a low of .65 for the Heat shop. An even higher degree of correlation was found between "enhanced" vehicles and manpower than existed between actual vehicles and manpower in the preceding analysis.

Table 2 below summarizes the results of the regression analyses discussed above.

	Factors	Correlation Low	Correlation High
1.	Acres to Manpower	.23	.43
2.	Population to Manpower	.50	.75
3.	MSF to Manpower	.63	.86
4.	Base Cost to Manpower	.63	.82
5.	Housing to Manpower	.37	.69
6.	Buildings to Manpower	.39	.69
7.	Work Orders to Manpower	.61	.74
8.	Job Orders to Manpower	.60	.78
9.	Crews to Manpower	.29	.46
10.	Enhanced Crews to Manpower	.41	.49
11.	Vehicles* to Manpower	.62	.94
12.	Enhanced Vehicles* to Manpower	.66	.96

*per 100 jobs

Table 2. Summary of Regression Analyses

Chapter Four

CONCLUSIONS AND RECOMMENDATIONS

The purpose of this study was to prove/disprove that the current Table of Allowances (TA) for general purpose vehicles does not allow the Base Civil Engineer an adequate number of vehicles to productively employ the unit's workforce. And, as a result, to recommend a better Basis of Issue (BOI) for the general purpose vehicle portion of the TA.

SUMMARY

1. Industry provides approximently one vehicle per every worker. The linear equation that represents a one vehicle for every person relationship is Y=X (X=number of shop personnel; Y=number of vehicles required). Based upon a survey of 20 companies, industry provides one vehicle for every 1.1 workers, nearly a one-to-one relationship. The linear equation representing this information is Y=.89X.

2. Table of Allowances 010 allows each BCE shop a certain number of vehicles based upon its manpower strength. The linear equation presently used to determines the carpentry shop's vehicle allowance is: Y=.25+.125X (1 vehicle/8 workers). The equation for the other four shops evaluated in this study (Plumbing, Heat, Refrigeration and Air Conditioning,

and Interior Electric Shops) is: Y=.25+.25X (1 vehicle/4 workers).

3. Industry carefully controls cost and provides a mix of vehicles that ensures their workforce remains productive to maximize profits.

4. Industry provides over 300 percent more vehicles per worker than the BCE is allowed (based on the differences in the above equations, i.e. .89/.25=3.56 or 356 percent).

5. The coefficient of correlation analyses found that shop manpower strengths have a high degree of correlation (relationship) with three workload factors: Total base floor space, total base facility cost, and base population.

6. There is excellent correlation between shop manpower, and the number of vehicles required, based upon the crew sizes of a sample of 100 jobs. The crew sizes were developed by applying existing Civil Engineering Engineered Performance Standards to each job and determining the crew size.

CONCLUSIONS

1. The industries vehicle allowance policies are based upon the ability to make a profit, and as such, not directly applicable to the Air Force. However, both industry and the AF, have a goal to maximize workforce productivity. The industry policy works; their successes appear to attest to that. Consequently, in light of the allowance differences, the AF should be able to improve productivity by increasing the BCE's vehicle allowances.

2. The present equation for calculating vehicle allowances, Y=.25+.25X, is based upon shop manpower strengths, i.e. the equation's given variable is manpower. This study found that significant correlation exists between manpower and three workload factors. Therefore, manpower remains the best measure of workload.

3. The most significant degree of correlation found in this study existed between the production output factor of number of vehicles required (using crew sizes developed from Engineered Performance Standards) and manpower.

4. Therefore, the results described in 2 and 3 above should be used to determine civil engineering vehicle allowances by calculating a new vehicle allowance equation applicable to the entire Air Force.

5. The newly calculated, vehicle allowance equation, Y=.4+.5X represents a linear relationship equation (Appendix F details the derivation process). The straight line (linear) is the one that best fits the data for all 25 bases used to calculate it. Therefore, this equation can be used to determine the vehicle allowances for any of the five shops evaluated in this study, for any Air Force base. The only information required is the particular shop's manpower strength.

The following graph depicts these various equations and their relationships.

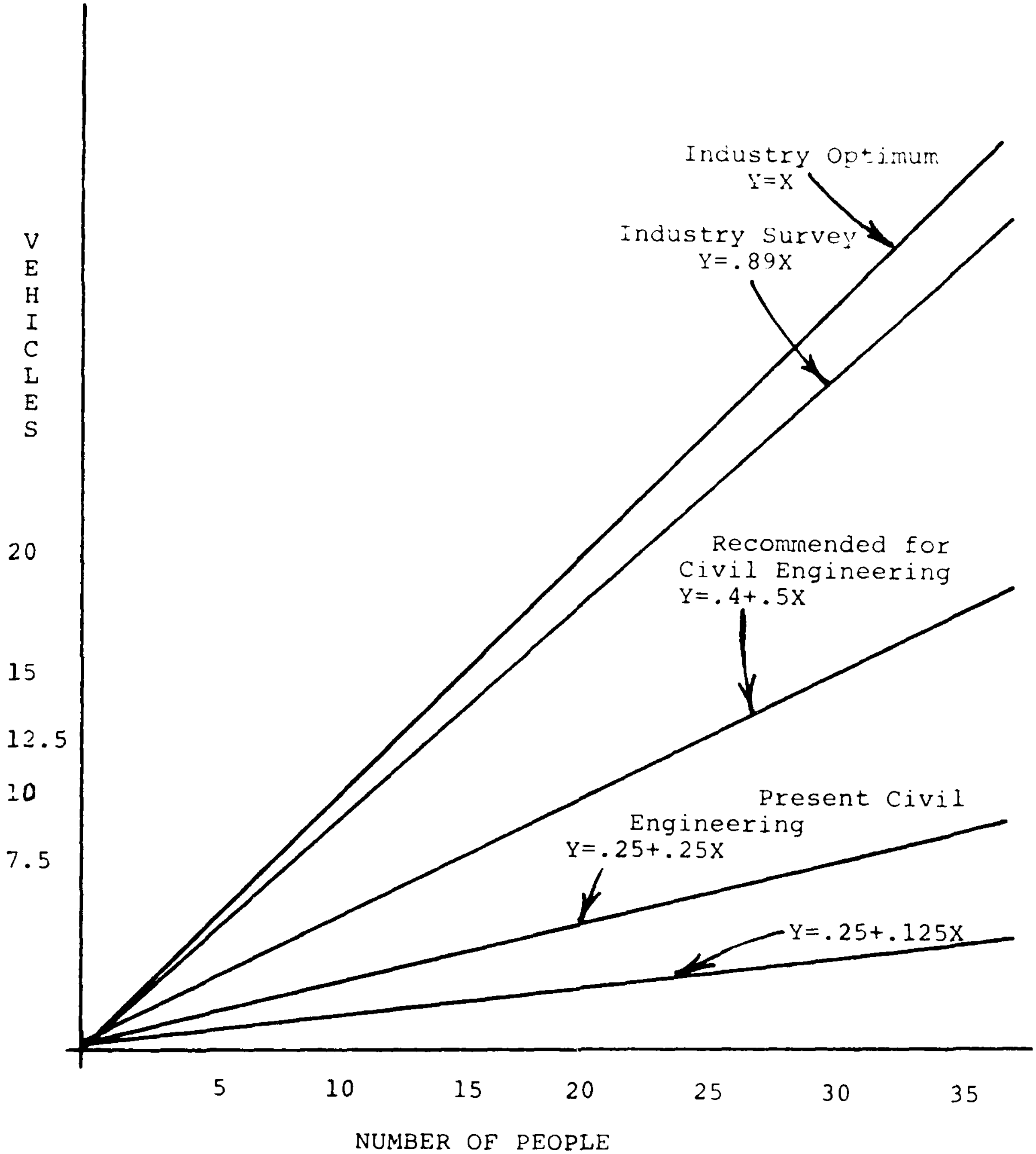

Figure 1. Manpower versus Vehicle Requirements

RECOMMENDATIONS

1. Recommend a new vehicle allowance equation be developed using shop manpower, as the given variable, and vehicles required, as the variable to be predicted. This equation will define the civil engineering general purpose vehicle allowances when a shop's manpower strength is known.

2. Recommend this equation be incorporated in the Air Force Table of Allowances 010 as the new Basis of Issue for the Carpentry, Plumbing, Refrigeration and Air Conditioning, Heating, and Interior Electric shops.

3. Recommend this equation be Y=.4+.5X (1 vehicle/2 workers)

4. Recommend the Hq Air Force Engineering and Services Center (AFESC) request Warner Robins Air Logistics Center (WR-ALC) adopt this equation for the Basis of Issue of Air Force Civil Engineering General Purpose Vehicles.

5. Suggest this study be included in the ongoing Air Force Civil Engineering evaluation of TA 010 allowances directed in the Air Force Engineering and Services Strategic Plan (see Appendix G).

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APPENDICES

APPENDIX A

TABLE OF ALLOWANCES 010 EXTRACT
"CIVIL ENGINEERING GENERAL PURPOSE VEHICLES"

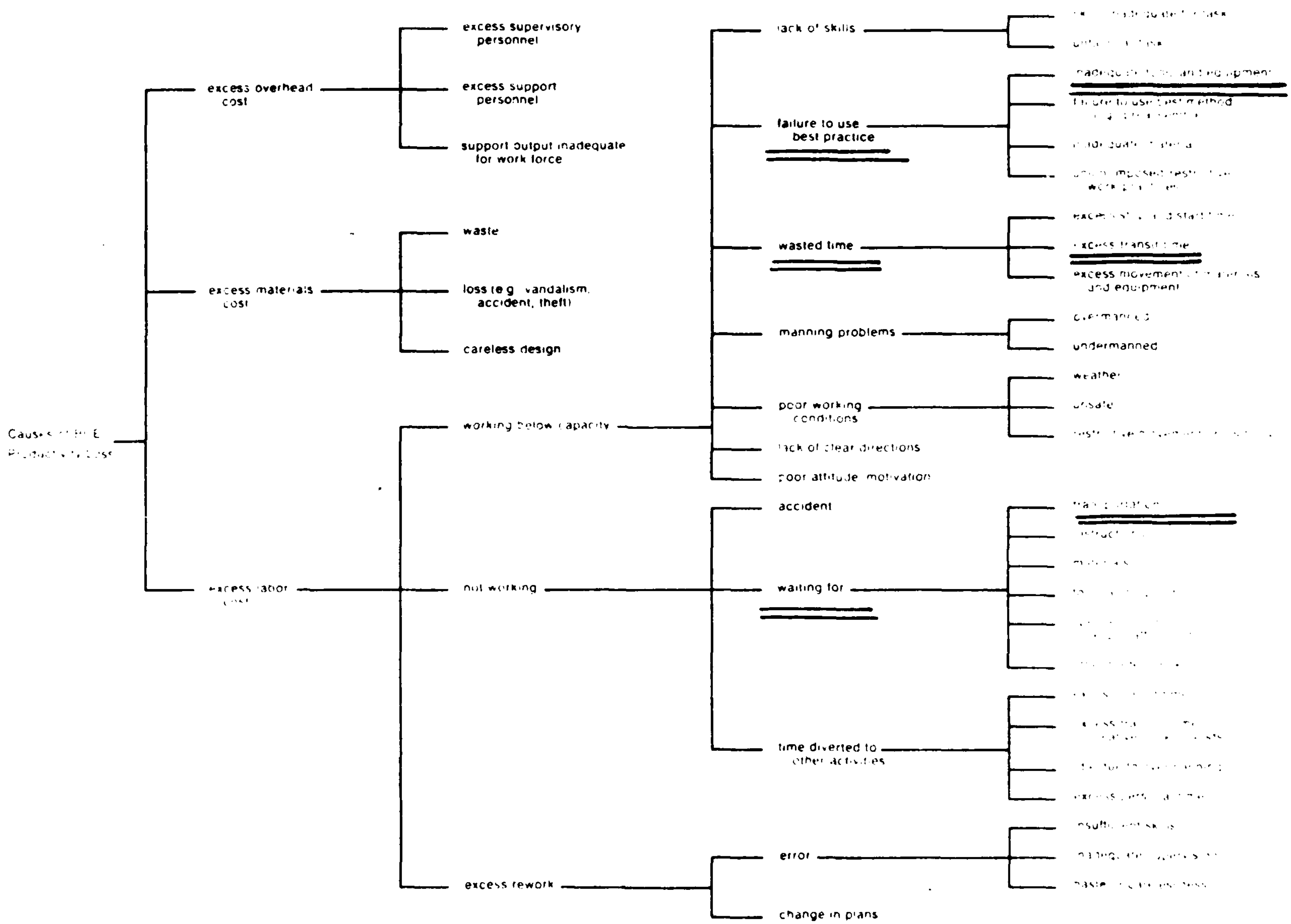
Stock Number Nomenclature	Column Basis of Issue
2320-00-702-5877 Truck Multistop 4X2 PN Milt 45338 Note - Applies to BOI (s) G-H, J, K, L, M, (truck P/UP/TRK/S-P may be auth within HQ AFLC approved ceilings when combined quantities do not exceed this BOI).	G 1 per each established BCE shop when minimum of 3 maint people asgn. H 1 addn vehicle for interior electric, plumbing, refrig/air cond(excluding plant operators), power production (excluding plant operators), heating (excluding fixed plant operators), family housing & appliance shops for each 4 addn maint people asgn. J 1 addn vehicle for carpenter, paint, mason, liquid fuels, metal, water waste & entomology shops for each 8 addn maint people asgn.

APPENDIX

APPENDIX B

CHART

"CAUSES OF BCE PRODUCTIVITY LOSS CHART"


excess overhead cost
excess materials cost
excess supervisory personnel
excess support personnel
support output inadequate for work force
waste
loss (e.g. vandalism, accident, theft)
careless design
working below capacity
not working
excess rework
lack of skills
failure to use best practice
wasted time
manning problems
poor working conditions
lack of clear directions
poor attitude motivation
accident
waiting for
time diverted to other activities
error
change in plans
excess movement
and equipment
undermanned
weather
unsafe

APPENDIX C

NAMES AND LOCATIONS OF INDUSTRIES SURVEYED

1.	Ace Plumbing	Arlington, Virginia
2.	Alabama Gas	Montgomery, Alabama
3.	Alabama Power	Montgomery, Alabama
4.	Arlington Cable	Arlington, Virginia
5.	Arlington Electric	Arlington, Virginia
6.	B & B Construction	Belleville, Illinois
7.	Bel-O Heating & Air Conditioning	O'Fallon, Illinois
8.	Continental Cable	Belleville, Illinois
9.	Electrical Contractor's	Arlington, Virginia
10.	Johnson Plumbing & Heating	Arlington, Virginia
11.	Payne's Heating & Air Conditioning	Montgomery, Alabama
12.	Sears Inc.	Arlington, Virginia
13.	Sears Inc.	Montgomery, Alabama
14.	Sears Inc.	O'Fallon, Illinois
15.	Sears Inc.	Springfield, Virginia
16.	South Central Bell	Belleville, Illinois
17.	Southern Bell	Montgomery, Alabama
18.	Storer Cable	Montgomery, Alabama
19.	Thompson Plumbing	Arlington, Virginia
20.	Virginia Electric & Power Company	Arlington, Virginia

APPENDIX D

LIST OF BASES SAMPLED

	BASE	COMMAND
1.	Altus AFB, Oklahoma	MAC
2.	Andrews AFB, Maryland	MAC
3.	Bolling AFB, Washington, D.C.	MAC
4.	Charleston AFB, South Carolina	MAC
5.	Columbus AFB, Mississippi	ATC
6.	Dover AFB, Delaware	MAC
7.	Eglin AFB, Florida	AFSC
8.	George AFB, California	TAC
9.	Grand Forks AFB, North Dakota	SAC
10.	Hurlburt AFB, Florida	MAC
11.	Kirtland AFB, New Mexico	MAC
12.	Little Rock AFB, Arkansas	MAC
13.	March AFB, California	SAC
14.	Maxwell AFB, Alabama	AU
15.	McChord AFB, Washington	MAC
16.	McGuire AFB, New Jersey	MAC
17.	Minot AFB, North Dakota	SAC
18.	Nellis AFB, Nevada	TAC
19.	Norton AFB, California	MAC
20.	Pease AFB, Massachusetts	SAC
21.	Pope AFB, North Carolina	MAC
22.	Scott AFB, Illinois	MAC
23.	Sheppard AFB, Texas	ATC
24.	Travis AFB, California	MAC
25.	Tyndall AFB, Florida	TAC

APPENDIX

APPENDIX E

"WORKLOAD, PRODUCTION OUTPUT, AND

MANPOWER DATA USED FOR

CORRELATION ANALYSIS"

TABLE 3

BASE ACREAGE

1.*	4113	10.	1093	18.	11274
2.	4206	11.	51330	19.	2407
3.	604	12.	6919	20.	4374
4.	3772	13.	7117	21.	1750
5.	4606	14.	2523	22.	3000
6.	3600	15.	4609	23.	5000
7.	40000	16.	3552	24.	6170
8.	5347	17.	5050	25.	28000
9.	6912				

TABLE 4

THE BASE MILITARY AND CIVILIAN POPULATION

1.	4384	10.	3924	18.	10282
2.	8596	11.	16966	19.	8194
3.	2719	12.	6995	20.	4125
4.	8748	13.	5663	21.	4451
5.	3878	14.	6257	22.	9836
6.	6200	15.	7406	23.	11205
7.	13265	16.	6600	24.	11363
8.	5623	17.	6235	25.	5448
9.	5585				

TABLE 5

MILLION SQUARE FEET OF FLOOR SPACE

1.	2.921	10.	2.013	18.	5.428
2.	7.974	11.	8.417	19.	5.880
3.	3.552	12.	4.319	20.	3.749
4.	3.806	13.	3.671	21.	2.188
5.	2.453	14.	4.295	22.	5.617
6.	4.928	15.	4.246	23.	6.815
7.	8.871	16.	5.806	24.	7.719
8.	2.975	17.	5.604	25.	4.027
9.	6.485				

*Refer to appendix D for base names.

TABLE 6

VALUE OF BASE FACILITIES($ MILLION)

1.*	90.6	10.	48.1	18.	165.5
2.	251.1	11.	218.4	19.	113.7
3.	91.3	12.	121.9	20.	113.7
4.	91.1	13.	123.7	21.	54.4
5.	77.5	14.	85.6	22.	152.4
6.	142.6	15.	85.6	23.	166.3
7.	235.2	16.	147.7	24.	204.9
8.	83.5	17.	156.1	25.	118.7
9.	161.6				

TABLE 7

THE TOTAL NUMBER OF BASE MILITARY FAMILY HOUSING UNITS

1.	800	10.	380	18.	1497
2.	2088	11.	2134	19.	264
3.	1396	12.	1535	20.	1211
4.	955	13.	711	21.	459
5.	820	14.	633	22.	1873
6.	1656	15.	993	23.	1287
7.	2336	16.	1754	24.	2167
8.	1541	17.	2470	25.	1171
9.	2113				

TABLE 8

THE TOTAL NUMBER OF BASE BUILDINGS

1.	898	10.	417	18.	1756
2.	1195	11.	2506	19.	477
3.	358	12.	1100	20.	542
4.	870	13.	795	21.	423
5.	627	14.	768	22.	879
6.	599	15.	1386	23.	1116
7.	1927	16.	671	24.	1817
8.	551	17.	785	25.	997
9.	1297				

*Refer to appendix D for base names.

TABLE 9

THE AVERAGE NUMBER OF WORK ORDERS ACCOMPLISHED BY THE BCE UNIT EACH MONTH

1.*	12	10.	13	18.	25
2.	41	11.	29	19.	21
3.	11	12.	19	20.	11
4.	16	13.	17	21.	23
5.	14	14.	20	22.	21
6.	15	15.	21	23.	26
7.	54	16.	19	24.	19
8.	20	17.	18	25.	18
9.	19				

TABLE 10

THE AVERAGE NUMBER OF JOB ORDERS COMPLETED BY THE FIVE SHOPS EACH MONTH

1.	142	10.	300	18.	420
2.	440	11.	520	19.	385
3.	102	12.	400	20.	225
4.	189	13.	360	21.	420
5.	212	14.	310	22.	445
6.	250	15.	320	23.	595
7.	760	16.	400	24.	350
8.	206	17.	360	25.	325
9.	210				

TABLE 11

THE CARPENTRY SHOP'S AUTHORIZED MANPOWER STRENGTH

1.	11	10.	13	18.	26
2.	33	11.	36	19.	25
3.	23	12.	34	20.	11
4.	17	13.	18	21.	13
5.	9	14.	23	22.	23
6.	24	15.	16	23.	31
7.	28	16.	29	24.	31
8.	15	17.	25	25.	19
9.	21				

*Refer to appendix D for base names.

TABLE 12

CARPENTRY SHOP'S GENERAL PURPOSE VEHICLE ALLOWANCE

1.*	2	10.	2	18.	4
2.	5	11.	5	19.	5
3.	3	12.	5	20.	2
4.	3	13.	3	21.	2
5.	2	14.	3	22.	3
6.	4	15.	3	23.	4
7.	4	16.	4	24.	4
8.	2	17.	4	25.	3
9.	3				

TABLE 13

THE PLUMBING SHOP'S AUTHORIZED MANPOWER STRENGTH

1.	12	10.	12	18.	23
2.	22	11.	25	19.	26
3.	15	12.	27	20.	13
4.	14	13.	25	21.	7
5.	10	14.	11	22.	16
6.	15	15.	18	23.	23
7.	27	16.	19	24.	26
8.	15	17.	19	25.	16
9.	15				

TABLE 14

PLUMBING SHOP'S GENERAL PURPOSE VEHICLE ALLOWANCE

1.	3	10.	3	18.	6
2.	6	11.	7	19.	7
3.	4	12.	7	20.	3
4.	4	13.	7	21.	2
5.	3	14.	3	22.	4
6.	4	15.	5	23.	6
7.	7	16.	5	24.	7
8.	4	17.	5	25.	4
9.	4				

*Refer to appendix D for base names.

TABLE 15

THE REFRIGERATION AND AIR CONDITIONING SHOP's AUTHORIZED MANPOWER STRENGTH

1.*	16	10.	16	18.	28
2.	35	11.	19	19.	31
3.	25	12.	35	20.	8
4.	14	13.	29	21.	14
5.	12	14.	15	22.	29
6.	18	15.	14	23.	40
7.	50	16.	29	24.	18
8.	15	17.	12	25.	22
9.	14				

TABLE 16

THE REFRIGERATION AND AIR CONDITIONING SHOP'S GENERAL PURPOSE VEHICLE ALLOWANCE

1.	4	10.	4	18.	7
2.	9	11.	5	19.	8
3.	6	12.	9	20.	2
4.	4	13.	7	21.	4
5.	3	14.	4	22.	7
6.	5	15.	4	23.	10
7.	13	16.	7	24.	5
8.	4	17.	3	25.	6
9.	4				

TABLE 17

THE HEAT SHOP'S AUTHORIZED MANPOWER STRENGTH

1.	19	10.	20	18.	20
2.	38	11.	23	19.	38
3.	29	12.	21	20.	18
4.	14	13.	22	21.	10
5.	12	14.	30	22.	15
6.	14	15.	18	23.	26
7.	50	16.	30	24.	26
8.	22	17.	17	25.	23
9.	19				

*Refer to appendix D for base names.

TABLE 18

THE HEAT SHOP'S GENERAL PURPOSE VEHICLE ALLOWANCE

1.*	5	10.	5	18.	5
2.	10	11.	6	19.	10
3.	7	12.	5	20.	5
4.	4	13.	5	21.	3
5.	3	14.	8	22.	4
6.	4	15.	5	23.	7
7.	11	16.	8	24.	7
8.	5	17.	4	25.	6
9.	5				

TABLE 19

THE INTERIOR ELECTRIC SHOP'S
AUTHORIZED MANPOWER STRENGTH

1.	11	10.	8	18.	15
2.	30	11.	16	19.	18
3.	12	12.	17	20.	11
4.	14	13.	26	21.	7
5.	6	14.	8	22.	20
6.	16	15.	18	23.	18
7.	33	16.	20	24.	19
8.	8	17.	25	25.	12
9.	29				

TABLE 20

THE INTERIOR ELECTRIC SHOP'S
GENERAL PURPOSE VEHICLE ALLOWANCE

1.	3	10.	2	18.	4
2.	8	11.	4	19.	5
3.	3	12.	4	20.	3
4.	4	13.	7	21.	2
5.	2	14.	2	22.	5
6.	4	15.	5	23.	5
7.	8	16.	5	24.	5
8.	2	17.	7	25.	3
9.	7				

*Refer to appendix D for base names.

TABLE 21

TOTAL BCE PERSONNEL

1.*	349	10.	338	18.	529
2.	758	11.	633	19.	475
3.	366	12.	518	20.	373
4.	412	13.	436	21.	298
5.	322	14.	428	22.	524
6.	477	15.	450	23.	521
7.	980	16.	535	24.	595
8.	412	17.	545	25.	486
9.	517				

TABLE 22

THE ACTUAL NUMBER OF CREWS USED TO ACCOMPLISH 100 JOBS (BASED ON A SAMPLE OF 100 JOBS ACCOMPLISHED BY THE FIVE SHOPS)

1.	31	10.	32	18.	36
2.	20	11.	36	19.	41
3.	47	12.	39	20.	34
4.	36	13.	34	21.	36
5.	41	14.	31	22.	42
6.	33	15.	36	23.	34
7.	44	16.	38	24.	36
8.	39	17.	39	25.	40
9.	36				

TABLE 23

THE NUMBER OF CREWS USED TO ACCOMPLISH 100 JOBS (CREWS BASED ON ENGINEERED PERFORMANCE STANDARDS)

1.	47	10.	51	18.	45
2.	41	11.	51	19.	46
3.	48	12.	44	20.	43
4.	47	13.	54	21.	43
5.	44	14.	47	22.	43
6.	44	15.	57	23.	52
7.	56	16.	42	24.	49
8.	50	17.	48	25.	45
9.	48				

*Refer to appendix D for base names.

TABLE 24

THE NUMBER OF VEHICLES REQUIRED FOR THE CREWS REQUIRED IN TABLE 22

1.*	4	10.	4	18.	8
2.	5	11.	9	19.	11
3.	7	12.	11	20.	4
4.	5	13.	9	21.	3
5.	4	14.	3	22.	7
6.	5	15.	6	23.	8
7.	12	16.	7	24.	9
8.	6	17.	7	25.	6
9.	5				

TABLE 25

THE NUMBER OF VEHICLES REQUIRED FOR THE CREWS REQUIRED IN TABLE 23

1.	6	10.	6	18.	10
2.	9	11.	13	19.	12
3.	7	12.	11	20.	6
4.	7	13.	14	21.	3
5.	4	14.	5	22.	7
6.	7	15.	10	23.	12
7.	15	16.	8	24.	13
8.	8	17.	9	25.	7
9.	7				

*Refer to apppendix D for base names.

TABLE 26

BREAKOUT OF ACTUAL NUMBER OF CREWS
(TO ACCOMPLISH 100 JOBS)

	1 Man Crews	2 Man Crews	3 Man Crews
1.*	0	65	35
2.	10	40	50
3.	40	40	20
4.	20	25	55
5.	30	30	40
6.	10	40	50
7.	34	40	26
8.	23	40	37
9.	15	48	37
10.	12	30	58
11.	20	25	55
12.	19	35	46
13.	12	40	48
14.	8	35	57
15.	21	28	51
16.	20	45	35
17.	19	60	21
18.	14	49	37
19.	27	39	33
20.	10	55	35
21.	10	75	15
22.	20	78	2
23.	10	49	41
24.	23	70	7
25.	16	48	36

*Refer to appendix D for base names.

TABLE 27

BREAKOUT OF NUMBER OF CREWS BASED ON APPLICATION OF ENGINEERED PERFORMANCE STANDARDS

	1 Man Crews	2 Man Crews	3 Man Crews
1.*	40	35	25
2.	30	35	35
3.	40	50	10
4.	40	40	20
5.	30	60	10
6.	40	20	40
7.	64	25	11
8.	54	11	36
9.	42	40	18
10.	50	35	15
11.	52	25	23
12.	25	58	17
13.	55	40	5
14.	41	40	19
15.	65	25	10
16.	24	65	11
17.	40	50	10
18.	38	35	27
19.	39	40	21
20.	33	33	34
21.	28	60	12
22.	24	70	6
23.	50	45	5
24.	25	50	25
25.	33	52	15

*Refer to appendix D for base names.

APPENDIX F

RECOMMENDED BASIS OF ISSUE (BOI) EQUATION DERIVATION

The equation Y=.4+.5X (X=shop manpower and Y= shop general purpose vehicle allowance) is a linear equation. The purpose of a linear equation is to provide a method of predicting the value of one variable, given the value of another. The general form of a linear equation is Y=a+bX, X is the given (independent) variable and Y is the predicted (dependent) variable. The equation Y=.4+.5X was derived as follows:

1. Find the value of a and b by using the statistical regression technique of least squares. The least squares equations for calculating a and b are:

$$a= \frac{(\Sigma Y)\ (\Sigma X)^{2} - (\Sigma X)\ (\Sigma XY)}{N\ (\Sigma X^{2}) - (\Sigma X)}$$

$$b= \frac{N\ (\Sigma XY) - (\Sigma X)\ (\Sigma Y)}{N\ (\Sigma X^{2}) - (\Sigma X)}$$

N=the number of pairs of data, which is 25 in this case (25 bases). Σ=the sum of the particular calculation, for each of the N pairs of data.

2. This study concluded that workload and production output were best represented by a and b below.

a. Shop manpower strength represents shop workload.

b. Number of vehicles required (standards) to do 100 jobs represents production output (based on a determination of crew sizes according to Engineered Performance Standards).

3. Therefore, manpower will be the given variable X, and the number of vehicles required (standards) will be the variable Y.

In order to find an equation applicable to all five shops, manpower data for the five were averaged. Using the average, the number of vehicles required were determined for each of the 25 bases. The steps followed to determine the number of vehicles required, based upon crews required to do 100 jobs, are:

1. Tabulate the number of 1, 2, and 3 man crews that accomplished each job. For example, number of 1 man crews=10, number of 2 man crews=55, and number of 3 man crews=35.

2. Calculate each categories percentage of the total. Since the sample consisted of 100 jobs, the percentages are 10, 55, and 35.

3. Determine the ratio of vehicles required to crew size. That is, divide each category percentage by its crew size. Each 1 man job requires 1 vehicle, each 2 man job requires 1/2 vehicle/person, each 3 man job requires 1/3 vehicles/person, etc, for example 10/1=10, 55/2=27.5, and 35/3=11.5. Divide each by 100 to get a percent ratio: .10, .275, and .115.

4. Add the ratio percentages together and multiply their sum by shop manpower. E.g. .10+.275+.115=.49 times 10 (10 person shop) =4.9.

5. Multiply these results by .7 to get the vehicle requirements/shop. .7 or 70 percent was assumed to be the

amount of trips taken using general purpose vehicles. The remaining 30 percent was assumed to be by some other means, for example, special purpose vehicles or taxi. Thus, for the example 4.9 times .7 = 3.4. A 10 person shop with this break-out of crews, needs 3.4 or 4 vehicles to properly do its job.

Now that the above 5 steps have been done for 25 bases, the linear equation regression technique of least squares can be applied. Using the calculated average manpower strengths and the calculated vehicle requirements, the calculated equation is Y=.407+.498X, which rounds to Y=.4+.5X. The coefficient of correlation for these two variables is .993. Therefore, this equation is an excellent model of vehicle needs. The 25 pairs (25 bases) of data used to calculate this equation are:

X-average manpower strengths			Y-vehicle requirements		
14	32	21	7	13	10
17	10	18	8	4	8
38	15	20	21	8	10
13	22	29	7	11	12
23	17	17	12	8	10
25	20	22	11	10	10
28	12	10	13	5	4
21	28	24	9	15	12
18			8		

APPENDIX

APPENDIX G

EXCERPT OF

"USAF ENGINEERING AND SERVICES

STRATEGIC PLAN"

REVIEWING TABLE OF ALLOWANCES

1512 TA REVIEW AND EQUIPMENT ACQUISITION

Last Update: 13 Sep 83
OPR: PQP (Capt. Coullahan, x6295)

Review, modernize, and expand table of allowance (TAs) and acquire more modern and efficient vehicles, shop tools, radios, etc., to improve the productivity and efficiency of engineering and services' (E&S) operations.

Milestone Date	Event	Status
AUG 83	Develop list of TAs used by E&S	Complete
JUN 84	Complete BCE vehicle FMI	
JUN 84	Complete initial TA update Investigative Engineering Project	
JUL 84	Establish process for systematic update of TAs used by E&S	
JAN 86	Complete initial review cycle of TAs used by E&S	Continuing

REQUIREMENT: The Air Force currently has 24 TAs which are used by E&S to perform their peacetime and wartime taskings. A systematic approach for review, modernization, and expansion of these TAs is not in use. Modernization and expansion of the TAs would lead to improved productivity and efficiency of E&S operations. WRM TA inputs for the E&S community have been primarily through intense HQ AFESC participation and intervention. The vehicle TAs used by E&S are updated based on individual base requests which manage to flow through the lengthy requirements justification process. Rarely are the vehicle TAs updated under a systematic review approach. Peacetime TAs used by E&S, for the most part, have not been reviewed in total to ensure state-of-the-art capabilities are provided. In summary, all reviews are on a hit or miss basis. Therefore, a new approach needs to be taken by the E&S community to ensure a modern capability exists to do the job.

CURRENT EFFORT: WRM TAs used by E&S have recently undergone review and update. This was due to recognition that ineffective logistics support and insufficient funding levels, in the past, contributed to a widening gap between operational requirements and E&S support capability.

The USAF/IG will conduct Functional Management Inspection (FMI) in 1983-84 on BCE vehicle requirements, and should provide an AF-wide vehicle shortfall impact on BCE productivity useful in the TA update process. A test case investigative engineering (IE) study will be pursued to update one E&S TA and provide recommendations on a systematic approach for the remaining E&S TA updates. AF directive changes will be pursued to ensure E&S requirements are systematically considered during WRM TA improvement actions.

INTERFACE: AFESC/DEM/DEO/DEH, MAJCOMs, ALCs, AFLC

FUNDING: IE Project FY 84 AFESC

PDP INFORMATION: N.A